ABSTRACT

SNCR Reagent Reduction Through Innovative System Controls at Salem Harbor Station Unit 3

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The NOxOUT® System installed on Unit #3 at New England Power's Salem Harbor Station has undergone a controls upgrade. The changes resulted in significantly lower reagent consumption and lower ammonia slip.

In order to implement the control changes, new hardware and software were installed with minimal intrusion in the plant routine operation. The new items include state-of-the-art temperature and ammonia monitors, remote liquid pressure control on existing twin-fluid injectors and computer hardware and software upgrade. New software takes advantage of furnace temperature enhancing the original steam feed-forward signal, and takes advantage of ammonia measurements enhancing in-furnace chemical distribution. Furnace temperature is also utilized to minimize ammonia spiking during rapid unit transients and to guide operators on improved sootblower usage.

This successful upgrade has provided New England Power's operators the ability to operate with significantly lower reagent consumption, lower ammonia emissions and lower ammonia in ash content for equivalent NOx reductions.

SUMMARY

Background

In 1993, New England Power elected to reduce the NOx emissions at their Salem Harbor Station, Units #1, #2, and #3 through the installation of Nalco Fuel Tech's NOxOUT SNCR technology[1]. These units are permitted on the basis of individually maintaining a 24-hour average NOx level of 0.33 lbs/MMBtu. The SNCR equipment installation and start-up on Unit #3 occurred in the third quarter of 1993 and was followed by installation and start-up of low-NOx burners with separated overfire air. Combined, these technologies have demonstrated consistent compliance with the mandated controlled NOx level while firing coal from a wide variety of sources[2].

In 1994, New England Power initiated an investigation into the applicability of continuous temperature and ammonia emission monitors for the ultimate purpose of integrating these signals into the SNCR control logic to improve overall SNCR system performance and lower operating cost[3]. In June, 1996, New England Power contracted Nalco Fuel Tech to provide new equipment, hardware and software on Unit #3 to upgrade the first generation control system.

The objectives of the team were to:

Lower Reagent Consumption

- Minimize Flue Gas and Fly Ash Ammonia Contamination
- Provide a more Precise System Control
- Provide Additional Operator Independence

Original NOxOUT System Description

Salem Harbor Unit #3 is a 156 MWe front-fired coal unit with a split furnace. Four mills supply each of four levels of burners.

The NOxOUT Process installed in 1993 had four levels of twin fluid injectors (air as the atomizing media) with two metering modules, one for the lower two levels of injectors, and one for the upper two levels of injectors. Each metering module had a mechanical liquid pressure regulator set at a fixed pressure. Liquid and air distribution modules located between the metering modules and injectors provide a means of balancing fluid flows and pressures to the individual injectors. Distribution of reagent within the treatment zone relies on droplet trajectory from the wall injectors and is accomplished by properly setting fluid parameters. The controls are comprised of an Allen-Bradley programmable logic controller with a computer interface for the operators facilitated by Factory Link software. The original installation had a then state-of-the-art 386 DOS based computer.

The NOxOUT Process is designed to minimally influence the operation of the combustion process. There are several key combustion/operational parameters which can positively or negatively affect the system reagent consumption and overall system performance (load, excess air, mills in service, sootblowing, ...). Treatment zone temperature and residence time for the SNCR reactions are among key drivers of performance limitations.

The NOxOUT Process originally installed on Unit #3 relied on load as the feed- forward signal. Load provides an indirect means of determining treatment zone temperature and residence time. Through an empirical optimization program, relationships were determined between load and injector levels in service (to track proper temperatures) reagent flow limits (maximum and minimum). These relationships were programmed into the Allen-Bradley "look-up" tables, one for each of four operating mill combinations. These "look-up" tables are configurable in up to 15 segments. The NOx feed-back fine-tuned an adjustment in the reagent feed rate within the limits set by the feed-forward load signal to hold a constant NOx setpoint for that load range, a value less than the target daily NOx average at all times. This feedback signal is effective during stable operation however, due to time lags in the control, slow to respond to rapid transients.

This control scheme relies heavily upon load to repeatedly reflect treatment zone temperature and residence time and hold acceptable performance based on the optimized settings. Operating parameters such as coal quality, mill performance, excess air, furnace cleanliness (sootblowing), burner performance, and others affect this repeatability and introduce variations which cause shifts in performance. Severe variations in these parameters called for operator intervention by way of manually over-riding characterized NOx setpoints or reagent flow limitations. Operators were aware that some parameter settings reduced reagent consumption (such as furnace sootblowing or reduced excess air), but rather than minimize reagent consumption, operations' main concern was remaining well below the NOx emission limit of 0.33 lb/MMBtu. As a result, NOx on average was overcontrolled with high reagent consumption and ammonia slip.

The Upgraded NOxOUT System Description

The NOxOUT Process controls were upgraded starting in September, 1996. Features for implementing the new control approach were built upon the old control approach so they could be activated progressively. The start-up procedure was carefully executed so as not to interrupt the system availability or reliability. Temperature and ammonia monitors were added, field wiring run, and final tie-ins done without interruption in service (the system was run in local manual for a short time during final tie-in).

Furnace treatment zone gas temperature is one of several major factors that affects the process performance. Providing an accurate signal to the controls and combining it with the load signal in the feed-forward part of the control is a way of minimizing shifts in performance described above. Two SpectraTemp ® optical pyrometers were installed in the furnace sidewalls above the furnace arch. The temperature indicated on the SpectraTemp output is an average of the temperature of particles at thermal equilibrium with the carrier flue gas in the instrument's 6° full cone field of view. In this way, the instrument effectively measures the average temperature along it's line of sight across the furnace. The use of two monitors allows operators a means of monitoring imbalance between the split furnace.

The uppermost zone of the original installation was taken out of service after the low-NOx burners and overfire air modifications were completed. This zone was placed back into service during this upgrade as an alternative supply to the remaining middle zone. This modification allowed operation of the two existing metering modules to supply reagent to an upstream (hotter) or downstream (cooler) zone in parallel. Two SpectraScan ® ammonia monitors were mounted on the rear wall at the economizer exit. These monitors use a technique called wavelength modulated laser absorption spectroscopy to monitor low concentrations of ammonia in the flue gas. These ammonia concentration control inputs are used to automatically bias chemical flow from one parallel operating zone to the other to minimize ammonia slip. One important advantage of the SpectraScan monitor is that the control signal is generated with very little real time lag between sample and readout (perhaps 15 seconds).

The metering modules perform the function of diluting stored reagent with water to provide enough liquid mass to the injection system for droplet trajectory to distribute the reagent in the reaction zone. Twin fluid injectors are utilized with air as the atomizing media. Air pressure is set manually at the distribution modules. The metering modules were modified to allow the remote control system to set the liquid pressure. This modification allows remote control of the droplet size distribution of the atomizers in service. Characterized tables were added to the controls (water pressure setpoint verses feed-forward signal) providing more precise control of this variable. Originally, only one setting was available for the entire mill combination/load range.

Water pressure control is also used in an innovative manner to allow for response to rapid furnace transients (formerly resulting overtreatment of NOx and in ammonia spikes). Droplet trajectory control of the twin-fluid wall injectors is possible by altering either the atomizing air pressure or the liquid pressure to the injectors in service. Air pressure is set at the distribution module and manually maintained within a narrow operating range. Decreasing liquid pressure with fixed air pressure causes a finer droplet pattern which does not penetrate and travel as far downstream in the furnace gases. By manipulating the liquid pressure, precise and immediate control of the treatment zone distribution is possible. This is used as a means of tracking rapid furnace transients. Should a sudden precipitous reduction occur in furnace temperature (such as is encountered when a mill trips, coal feed bridges,...), liquid pressure to the injectors is immediately reduced, lowering the treatment zone in the furnace and minimizing liquid feed during the short-lived transient. Change in temperature inputs (a derivative control) are used to track these transients and automatically move the liquid pressure as required.

The Central Control Console includes an Allen-Bradley PLC525 upgraded to accommodate the new discrete and analog inputs and outputs. The 386 DOS based computer was replaced with a Pentium Windows based computer. The computer acts as the operator interface with the controller using a program called Factory Link. The Factory Link program was reconfigured to the Windows environment. Operating data are presented on eighteen different screens. The new screens were configured as closely as possible to the old, but with the new features as discussed above as well as two others, the “high load setpoint adjust” and the “daily average chemical reduction” features. These last two features allow the operators to monitor and control the daily NOx average much more precisely than in the past.

The “high load setpoint adjust” is a software feature that takes advantage of the fact that lower NOx settings may be achieved more easily at low load. Therefore, the current daily NOx average is tracked and, as the day wears on, a setpoint is calculated which, if met for the balance of the day, would more than satisfy the 24 hour NOx average. At high load, this calculated setpoint is usually higher than the characterized setpoint and significant reagent savings are realized by defaulting to the higher setpoint. At low load, when low setpoints are easily achieved with low reagent flows, the system defaults to a lower setpoint.

The “daily average chemical reduction” feature also keeps track of the current daily NOx average. Towards the end of the 24 hour averaging period (midnight to midnight), a current daily NOx average is achieved which is low enough that even should the NOxOUT System be out of service for the remaining averaging period, the 24 hour NOx average would still be satisfied. The System defaults to minimum pumping rates at this time. Again, significant reagent savings are realized.

Results

The NOxOUT System now operates routinely with less than half the daily average reagent consumption. About half the reagent savings realized are due to lower furnace temperatures attendant with increased sootblowing. Operators are continuing to optimize the sootblowing cycle and develop new guidelines using the new furnace temperature monitors. Daily NOx average tracking has proven to be invaluable in minimizing treatment needs.

Gas phase ammonia has been reduced from 10 to 15 ppmv averages with peaks during transients over 40 ppmv to values consistently less than 5 ppmv. Ammonia on ash has been reduced by approximately half.

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